Cross-Domain Payload Migration

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Cross-Domain Payload Migration: Space payload development typically occurs over relatively long timelines, given the risks, costs, and other factors. This fact motivates developers to investigate other payloads and platforms, in aviation and terrestrial systems, for example, as a means of gaining experience with state-of-the-art technology and exercising the methods and processes used in engineering high-reliability space systems. Increasingly, systems developed for aviation and terrestrial platforms serve as risk-reducing prototypes for eventual space missions. Remote operation of payloads deployed in unmanned aviation platforms and unattended ground systems provides a realistic operating environment for simulating control of a space payload.

The tradespace of hardware and software required to successfully support many Navy, Marine Corps, and DoD missions exhibits commonality that could be used across multiple payload and platform domains. Comparison of characteristics and requirements between payload domains shows many solutions to be more alike than different. The Naval Research Laboratory has demonstrated on several payload developments the feasibility of designing advanced, state-of-the-art systems for use across multiple domains and the reduced development costs which result, especially for shared software systems.

Moving Beyond Single-Purpose Payloads: In examining the organizations, companies, laboratories, and other facilities often supporting DoD development activities, it is common to note a stovepiped mentality. The space development organizations tend to be separated from the aviation and ground solutions people. These structures often mirror that of the sponsoring organization, resulting from security classification, from separation of funding sources, and other factors. For a more than a decade, DoD has specifically focused on breaking down stovepipes so that within organizations there is more visibility across the portfolio of projects and development efforts. Current economic realities and the need to share information help bring down stovepiping.

The Naval Research Laboratory provides a unique environment to support those efforts with a broad multidisciplinary approach across our divisions. Since many of our sponsoring organizations are also in a position to see across the multiplatform solution space, they are able to recommend development projects and solutions that can end up being more efficient. Encouraging NRL scientists and engineers and our DoD sponsors to think ahead during the specification and design phase about applying their work across multiple domains is advantageous. In the Space Systems Development Department, it has been a philosophy to "solve the problem once" to the largest extent possible. We continue to strive to meet that ideal.

Case Study — Copperfield-2: The Copperfield-2 (CuF2) payload system for use in ground, aviation, and space platforms serves to demonstrate a core R&D product NRL has successfully demonstrated across multiple platforms. The CuF2 system was developed as an experimental platform for a flexible, reconfigurable payload. When the first concepts were put together, the design focused on a single type of aviation platform. However, as the architecture evolved, the engineers made design decisions and trades that supported "future proofing" the system and provided for expanded utility. With the broader capability designed into the hardware and software, CuF2 became a core product and acted as a springboard to a number of other unforeseen projects, each program adding further capability valuable to follow-on work. This produced a library of hardware and software applications, and a menu from which modular systems could be constructed. The history of the development shows the migration across platform domains.

Not all of the platforms and domains listed in Table 2 came to fruition in an actual demonstration, but in no case did a limitation of the payload design prevent further application. While CuF2 started life with a specific radio requirement in mind, its success has been defined by its capability to adapt to new signals that were of no interest when the payload was first designed.

Furthering Cross-Platform Applicability: As development continues with the next generation of payloads under the Software Reconfigurable Payload (SRP) portfolio of products, providing built-in flexibility becomes a design rule. The "best practices" used in the design, implementation, and construction of space payloads, with their higher complexity and expense, are also in line with the best practices one uses in the development and design of aviation payloads, and really help to increase the reliability of any system. Engineering trades must be undertaken to optimize capability versus cost, however: it is often difficult to articulate in a requirements document "latent capability."

The biggest challenge one finds in developing cross-domain solutions is selecting high-performance components for terrestrial and aviation applications that will also operate successfully in the higher radiation levels encountered in the space environment. Thermal, vibration and shock, and vacuum effects can

all be readily accommodated through careful management of the environmental control systems. Indeed, shock and vibration are often a more challenging problem in aviation and terrestrial systems — rocket rides are short in duration, and extremes of temperature are very unusual events. Sitting on the tarmac in the desert for 8 hours of sunlight often presents a more challenging thermal design problem than the one encountered in the design of space payloads. Figure 5 shows the variety of payload operating domains and corresponding packaging techniques.

Different types of electronic components used in payloads respond differently to radiation environments depending on their underlying technology. RF components are inherently more tolerant due to the semiconductor processes used to construct them. High-speed processors and field-programmable gate arrays (FPGAs) tend to be "softer" and can be affected by total-dose radiation, producing a slow degradation of performance, or by highly energetic bursts of radiation, causing "single-event upsets" that change memory states. Permanent failure may even result when a highly charged particle hits a particularly susceptible semiconductor device, causing "single-event burnout." In the realm of digital processing, radiation tolerant parts are available — but parts today tend to be at least a decade behind parts that are commercially available for use in terrestrial and aviation applications. NRL experience has shown that a compromise design with radiation-hardened circuitry, but much of the same software components, provides for the best portability for cross-domain applications. On-orbit experience has also shown that within the tradespace of cost, complexity, and reliability, selected commercial non-radiation-hardened components can be successfully flown and provide useful mission life. Sponsors must, however, understand the cost-benefit trade and the risks involved.

Conclusions: Payload design engineers have within their toolbox the ability to create systems that are relevant beyond a single operational domain. Keeping the most challenging attributes of each domain in mind during the design process, intelligent engineering trades can be made that maximize capability. NRL experience in providing terrestrial, aviation, and space platforms validates the flexibility, extensibility, and cost and schedule savings that may be realized. The goal of "solving the problem once" is obtainable, and in the longer term provides more capability to more payload systems with reduced overall cost.

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TABLE 2 — Payload Migration History

Platform	**Domain**	**Year**
Predator class UAS	Aviation	2001
Firescout class UAS	Aviation	2003
TacSat-1	Spacecraft	2004
Tier-II UAS	Aviation	2005-6
TIE/TacSat-2	Spacecraft	2006
Subsurface	Subsurface	2006-7
GlobalHawk	Aviation	2008
MSS	Terrestrial	2008
TacSat-1A	Spacecraft	2008/9

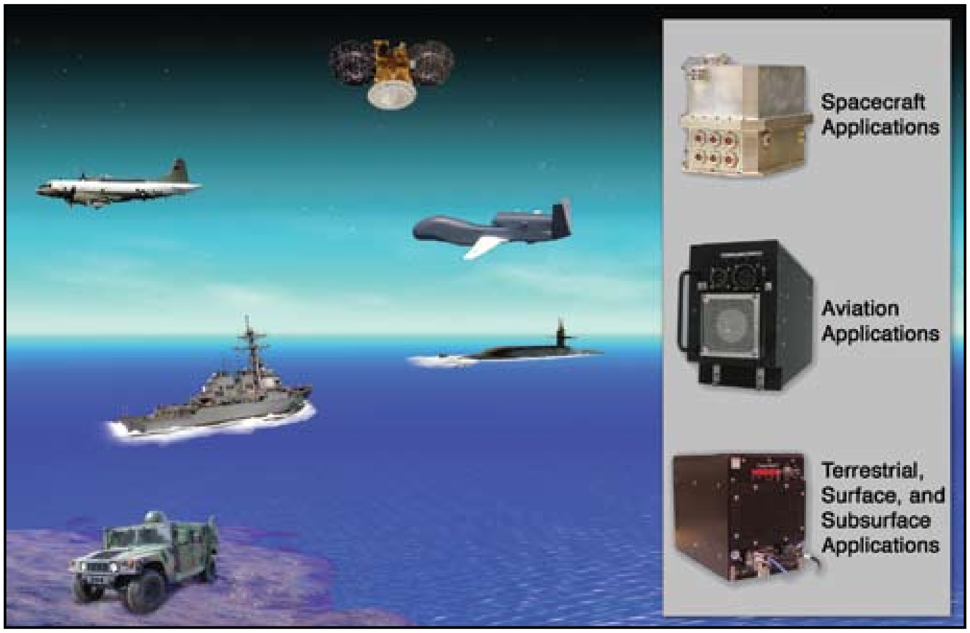

FIGURE 5
Various form factors and hardware examples for those domains.